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TEACHING PROBLEM-SOLVING SKILLS TO ADULTS

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Abstract

College teachers have done an excellent job over the years of teaching technical concepts, but they may not have done as good a job of teaching their adult students to be good problem-solvers. Nine representatives from the technical industry and academia were interviewed in this study for their expert opinions on the subject of teaching problem-solving skills to adult college students. Part I of the study defines problem-solving and explains the importance of teaching it. Part II summarizes some selected problem-solving methods from the available literature in an effort to understand what each has to offer. Part III offers recommendations for teaching problem-solving skills in vocational/technical classes at the college level.

Introduction

Not many years ago, college teachers planned and delivered their curriculum with little regard for the needs of the companies that would be hiring many of their graduates. Today, however, administrators and faculty from colleges and universities are involved in regular discussions with employers from business and industry about how best to educate and train students for the modern workplace. As a result of these discussions, educators find themselves continuously updating and revising their courses' technical content to meet the ever-changing needs of the employers, effectively addressing many of the inadequacies that employers have observed in the past. While technical skills may not be as much of an issue with employers now as they were formerly, the lack

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of "soft" skills are of increasing concern today. Soft skills include those skills, beyond technical training, that help an employee contribute to a company at an overall higher level than another employee with equivalent (or even superior) technical skills. These soft skills include, but are not limited to the ability to work in teams, to communicate, to listen effectively, to negotiate, to pay attention to detail, to apply principles of craftsmanship, and to solve problems. This study examines in detail the last of these; i.e. the ability to solve problems.

According to interviewee comments provided in this study, problem-solving is a skill that employers and supervisors value highly in their employees. All employers interviewed for this study claim that, as a result of changes in the work place, they look for evidence of problem-solving skills in prospective employees. In the past, front-line workers performed repetitive, mundane tasks until something, such as a machine failure, went wrong. The workers then reported the problem to some other group (usually their supervisor or engineering personnel), and then waited, nonproductively, until someone else was able to solve the problem. In today's workforce, however, front-line workers are expected to solve many of the problems they encounter. This is far more efficient and productive. Occasionally, more complex problems occur, problems that are beyond the capability of the front-line worker to resolve. In these instances, the workers are asked to involve other individuals who may have a more intimate knowledge of the operation. Unfortunately, the ability to solve problems effectively is an elusive skill that is not usually emphasized in college curricula, largely because it is much more difficult to teach than "book smarts" or technical skills. The reasons for this are explored in a later section of this paper. It is complicated by the fact that there are a myriad of published problem-solving methods, and little agreement exists among educators about how problem-solving skills can best be taught.

The following study was undertaken to explore the subject of teaching adults to be effective problem-solvers in the workplace. The goals of the study were 1) to determine the importance of teaching this skill, 2) to review and summarize some of the available literature on problem-solving methods, and 3) to compile some of the best practices

for incorporating problem-solving instruction into a college curriculum. With the exception of the literature portion, the information in this study was obtained by conducting personal interviews with selected representatives from high-tech companies and from technical colleges. The list of these panelists is included at the end of this paper. Panelists for this study were selected based on their interest in the topic, as well as their knowledge and experience with hiring and training technical professionals.

Part I–What is Problem Solving?

Problem-solving is an activity that many of us engage in multiple times each day. Some examples, given in order of increasing complexity include the following:

- What to wear today?
- Which route to take to work?
- How to get a machine working again?
- How to market a product?
- How to improve personal relationships?
- How to reverse global warming?

Some problems can be solved quickly; others may never be solved. Very simply, a problem involves a situation with one or more unknowns where there exists a desire to find, or know, the unknowns. Finding the unknowns is the process of problem-solving (Jonassen, 2000).

Problem-solving includes many levels of complexity. The simplest form involves looking up an answer in a reference. Only slightly more complicated is the form of problem-solving common to college homework problems, where the teacher and/or the textbook have previously worked out similar examples. Rarely, however, do problems in real life present themselves in such a well-structured form as a homework problem. It is the higher-order forms of problem-solving that are sought by employers.

True higher-order problem-solving is an open-ended process. The usual problems that are presented in life and in work are ill-defined and unexpected. Often there are consequences associated with not solving it

(other than a low homework score), and there are multiple possible solutions (Halpern, 1996). Students who are adept at solving lower-order problems are accustomed to the idea that there is always one right answer to a problem. It is this paradigm that makes higher-order problem-solving difficult for students. In the real world of life and employment, unlike the world in the back of a textbook, there is rarely one right answer. Professor Amy Moll, who teaches problem solving as part of an introductory engineering course at Boise State University, offered this realistic perspective: "Since there is usually time pressure involved, the goal may be simply to find the 'least bad' solution to the problem and move on to the next one" (Personal Inteview: Moll, Amy, Ph.D.; July 22, 2002).

Can Problem-Solving be Taught?

Even with little or no college-level training in problem-solving skills, some employees enter the workplace already possessing exceptional problem-solving ability. These people may possess an inherent aptitude for problem-solving, which may have been reinforced in their earlier educational experiences. However, the panelists involved with this study all agreed that students can improve their problem-solving abilities with the proper training. With the proper attention given to varied learning styles, appropriate learning activities can be designed to accomplish two important goals:

1. Expose adult learners to structured methods of approaching problems.
2. Develop an appreciation for why structured methods should be used when approaching problems.

Item 2 above is especially critical because many adults do not see the value in taking extra time to do the detailed groundwork and analysis that a thorough approach to problem-solving often entails.

Who is Responsible for Teaching Problem-Solving?

All interviewees in this study from both higher education and industry agreed that teaching problem-solving should be a high priority, and they share the responsibility for doing so equally. They also agreed that, until recently, industry has borne nearly 100% of this burden, and it is time for colleges to do more. Some went so far as to suggest that some technical content could be sacrificed in order to focus more on this skill.

College vocational/technical teachers should be responsible for introducing adult students to basic problem-solving concepts, key terminology, and methodology. With many methods to choose from, as will be seen in the second section of this paper, it is not reasonable to expect colleges to teach all of the methods, nor focus on any one. In addition, technical courses should include more open-ended problems, projects, and other instructional activities that force students to use problem-solving skills. They must then come up with creative ways to encourage and reward good problem-solving processes even in the absence of determining the "right answer."

Meanwhile, industry must assume the burden of providing any training that is specific to that company. For example, many companies use a specific problem-solving method. These companies should reinforce the use of problem-solving through specific examples that relate directly to their products and processes. They must also instill the discipline to use good problem-solving skills in everyday situations through the use of feedback mechanisms, such as the performance review.

Part II–A Selected Review of the Literature: A Comparison of Problem-Solving Methods

There is considerable literature on problem-solving, dating back to the 1940s. While there is some overlap in the various resources, each selected author has at least one unique element to add to the global picture of problem-solving. What follows are excerpts from selected references on the subject, grouped by theorist.

George Polya–A Pioneer of Problem-Solving

George Polya (1985) is a Hungarian immigrant who is considered one of the fathers of modern structured problem-solving. He maintained that problem-solving was something that could be taught. His method consists of four steps:

1. Understand the Problem
2. Devise a Plan
3. Carry Out the Plan
4. Look Back

Polya was one of the first to propose a step-wise approach to problem-solving. His method includes careful definition of the problem before implementing solutions and reflection at the end of the process to be sure the problem was completely solved.

Diane Halpern–Critical Thinking

Halpern (1996) does not list a specific step-by-step process. Instead, she offers many different strategies for approaching problems of various types. All of her strategies are in the framework of critical thinking; that is, not being locked into any particular method and being careful not to rely too much on what has worked in the past. She describes three stages in problem-solving (i.e. incubation, insight, and persistence).

AdvantEdge–Problem-Solving and Decision Making for Corporations

AdvantEdge (Alamo, 1995) is a consultant-delivered program designed to guide corporate employees through structured processes of problem-solving and decision-making. It frames the problem-solving process as a "structured cause analysis" under the premise that every problem has a cause. Once the cause of the problem is identified, the solution is not far behind. While this, too, may seem intuitive, it effec-

tively guides employees through thought processes that they may not have attempted formerly. The essence of AdvantEdge's structured cause analysis is summarized as follows:

1. Examine the problem until it is well understood and can be explicitly stated
2. Perform an inventory of the available facts
3. Identify the differences between the observed and comparative facts
4. Identify any recent changes that have triggered the problem
5. Generate a set of likely causes
6. Narrow the list of likely causes through testing

Steve Loomis–Problem-Solving to Meet Organizational Goals

In his graduate thesis, Loomis (1998) attempts to show how training in problem-solving can be made more effective. His method for doing this is to use a framework for problem-solving that forces the employee to understand in depth the finer points of what makes his or her organization unique. Having accomplished this, the employee is better equipped to deliver results that will help the organization to improve. In this context, the question is "Why are we not meeting our goals?" His problem-solving process includes the following five steps:

1. Clarify Organizational Expectations
2. Identify Accomplishments Necessary to Meet Organizational Objectives
3. Analyze Causes of Accomplishment Gaps
4. Plan and Implement Interventions
5. Revise

John Hayes–The Psychology of Problem-Solving

Hayes (1981) explores the different ways in which human beings approach problem-solving and ties this to known frameworks of the human mind. He presents six aspects of problem-solving: representation, invention, search for the solution, decision-making, memory, and

knowledge. His book, *The Complete Problem Solver*, is highly theoretical, but it does provide some problem-solving tools, including this version of a stepwise problem-solving method:

1. Finding the Problem
2. Representing the Problem
3. Planning the Solution
4. Carrying Out the Plan
5. Evaluating the Solution
6. Consolidating Gains

The last step represents Hayes' unique addition to the other problem-solving methods. In this step, he includes an additional post-problem reflection that assesses the whole problem-solving experience and that allows for adjustments based on any key learning.

Stephen Andriole–Problem-Solving as a Very Complex Process

Andriole (1983) presents a uniquely structured problem-solving process that is different from any discussed thus far. It includes the following five steps:

1. Assessment of Tools
2. Performance of Organizational Tasks
3. Problem Categorization
4. Solution Documentation
5. Defense

The last step is Andriole's unique addition to the subject. Once documented, the problem-solver still has to defend his or her work in varied environments "where multiple and sometimes hostile motives may be at work" (Andriole, 1983, p. 153). Andriole's most important contribution to the subject is the great detail he provides on the first three steps listed above. This level of thoroughness in problem-solving is necessary for the most complex situations.

Maridell Fryar and David Thomas–Problem-Solving for the Common Person

Fryar and Thomas (1979) have written a how-to manual for just about anyone to use. It is not long, and it is written in easy-to-read language. It conveys a generic approach to solving the many types of problems that life can deliver. They offer this step-by-step method:

1. Define and Limit the Problem
2. Analyze the problem and gather data
3. Establish criteria for possible solutions
4. Suggest all possible solutions
5. Select the best possible solution
6. Plan for implementing the solution

This approach breaks out the solution generation into three separate steps — 3, 4, and 5 — offering more guidance to this part of the process.

Arthur Whimbey and Jack Lochhead–What Makes a Good Problem-Solver

Whimbey and Lochhead (1980) do not give us a step-by-step approach to problem-solving. Instead, they explore the psychology of problem-solving. They try to answer the question, "Why are some people better at problem-solving than others?" They list five characteristics of successful problem-solvers:

1. Positive Attitude
2. Concern for Accuracy
3. Breaking the Problem Into Parts
4. Avoiding Guessing (i.e. when troubleshooting equipment, guessing often leads to the replacement of multiple components in hopes of finding the broken one. Meanwhile, several perfectly good components are sent out for repair, at considerable expense)
5. Activeness in Problem-Solving

John Arnold–Disciplined Problem-Solving for Businesses

Arnold's (1992) approach is unique and different from any described above. He delivers a three-step approach to solving very complex problems in a business environment. He then uses many real-life anecdotes to illustrate how each step can be used effectively. The three steps are:

1. Root Cause Analysis
2. Option Analysis
3. Risk Analysis

Part III–Teaching Problem-Solving Skills

The members of the panel in this study possessed varying degrees of experience in teaching problem-solving skills. Most suggested a two-part approach when teaching problem-solving. First, adult students must be introduced to theories, methods, and terminology of structured problem-solving. This can be accomplished in a traditional lecture format. Any of the published methods can be used as a foundation, but it is imperative that students realize that they are not bound to using only one method. Different types of problems call for different types of approaches. It is not necessary, and often not possible, to create a new course (e.g. Problem-Solving 101) although some educators have chosen to do so. The theory of problem-solving can be presented in a relatively short amount of time, and it can be easily be incorporated into an appropriate existing course.

The second, and by far most important, part of teaching problem-solving skills is incorporating the use of open-ended activities into as many of the existing classes as possible. Instructors should provide a short refresher on problem-solving concepts to students immediately before the selected activity. In the activity, students should be presented with a problem that utilizes technical concepts taught in the class, but the problem should be in a form unlike what they have seen previously in homework or other examples. The problem should be workable, but not easy to do. The problem should be crafted in such a manner as to require that students use tools, without being told which tool(s) to use.

It is important for the instructor to guide the students through the problem-solving process without leading them to the solution. Instructors may find this difficult to do. The activity must be structured to provide sufficient time for students to analyze the problem thoroughly and allow the option to continue the next day, or longer, if necessary. It is important to note that in the work place, however, time is rarely such a luxury, which can lead to bypassing important parts of the problem-solving process.

Another important part of the activity is to complete a "post mortem" after the process is concluded. The post mortem should include the following questions:

1. What was the final diagnosis and proposed solution?
2. What types of data were collected to diagnose the problem?
3. What hypotheses were generated?
4. Were you systematic or haphazard in your problem-solving?
5. How could you have improved your problem-solving methodology? (Polya, 1985)

Two Successful Case Studies

One of the most successful efforts to teach problem-solving was reported by Jim Dunn, an electronics instructor at Boise State University. During the first half of Dunn's Electronic Instrumentation course, students completed an assortment of standardized lab activities that involved breadboard circuits and test equipment. In the second half of the semester, the students were presented with an inoperative complex machine (a robotic chip handler) and a stack of manuals and schematic diagrams. The students were asked to solve a number of functionality problems on the machine. Having been briefed on the concepts of structured problem-solving, the students systematically worked through the various problems they encountered and successfully restored the machine to working order by the end of the semester!

In another case study, Mary Jane Willis of Albuquerque Technical Vocational Institute has developed an activity in which students were asked to their own companies. In this activity, the students worked

through all the details of starting up a company, including designing the facilities, hiring personnel, establishing budgets and financing, determining process flow, providing quality checks, etc. Then they were given a nebulous problem related to their companies to resolve, such as the following:

1. High employee attrition rate
2. Increase in customer returns
3. Low employee morale
4. Failure to meet production goals

Students were then tasked to use a structured problem-solving method to work through the problem and present their solution.

Complicating Factors to Teaching Problem-Solving

While many college instructors are aware of the trend towards the incorporation of more soft skills into college curricula, they are resistant to it. Instructors may be more confortable with a curriculum based entirely on technical competencies and find it easier to plan, deliver, and evaluate. They have been doing this for years, and they know how to do it. Incorporating soft skills, such as problem-solving, into a well-established class may create extreme discomfort for some instructors.

Soft skills, such as problem-solving, are generally more difficult to teach than technical skills for several reasons. First, while there is a large body of literature on problem-solving available, there is relatively little information on how to teach this effectively. Second, "book knowledge" is very easy to evaluate via traditional methods, such as multiple-choice exams; whereas evaluating problem-solving skills may be more subjective and require carefully designed assessments. Third, teaching problem-solving successfully involves more than just conveying information; it involves changing attitudes. Students must learn to appreciate why this skill is useful and important in order to be able to use it effectively. Fourth, in this increasingly technical society, schools are pressured to pack more and more technical content into a two-year or four-year program. Adding problem-solving into the mix meets with resistance due to the fact that some other important content may be sacrificed.

Finally, effectively teaching problem-solving necessitates much more instructor-to-student time. Instructors must help their students work through problem-solving exercises, preferably in a lab setting with a small number of students. In an era of increasing enrollments, when many classes are taught in a lecture hall to over 100 students, there are practical limitations to such personalized training.

This leads to another complicating factor to teaching problem-solving. The educators on the panel in this study observed that their adult students are resistant to learning soft skills. Students attend school for a variety of reasons, but rarely is "becoming a better team player" very high on the list. Usually they are motivated by an interest in the technical aspects of the field they have chosen. The instructors interviewed reported that their efforts to teach problem-solving have been frustrated by the observable tendency in students to "glaze over" when the topic is presented.

So it seems that we are trying to teach material that meets with almost universal resistance from both the students AND the instructors. A daunting task indeed!

Recommendations for Teaching Problem-Solving Skills to Adult Students

Each of the problem-solving methods described in Part II have advantages and disadvantages, but incorporating problem-solving skills is much more important than which method is used to do this. However, any attempt to teach students to be good problem-solvers should include some basic and important concepts.

First, regardless of the method used, the problem solving process should begin with a carefully crafted "problem statement." Articulating and agreeing upon such a statement not only presents all participants with a clear picture of the problem, it also forces all team members to work toward the same goal. An important part of this phase is a clear description of what the problem will look like when it is eventually solved, answering the question, "How will we know we are done?"

The second phase of teaching problem-solving skills involves data collection. Because problem-solving cannot be effective if there is not good data to work with, students must be shown how to gather useful data ("What do we know?"), to determine what data is still needed ("What don't we know?"), and to organize the data so that it provides useful information ("What is the data telling us?").

Third, instruction in problem-solving should include instruction and practice in the fine art of brainstorming. When multiple experts are involved, well organized brainstorming can lead to very creative solutions to problems.

Finally, problem-solving instruction must emphasize the need to follow-up and reflect after the process is believed to be concluded. This follow-up includes answering the question "Did we really solve the problem?" The question must be asked after sufficient time has passed to allow objective evaluation of the solution that was implemented and to ensure that the positive results observed were not just temporary. If the answer to this question is "No," then the problem-solving process must start again at the beginning. The follow-up phase should include reflection on the process that was used, in hopes of solving future problems more efficiently. It should also include proper documentation of the problem, the process, and the solution so that future occurrences of the problem, or similar problems, can be resolved more quickly. Because subsequent problems in need of solutions exist, this step may be unadvisedly overlooked in the work place.

Any of the stepwise methods listed in the previous section can be used as a foundation for teaching problem-solving as long as these important elements are emphasized.

Conclusions

There is near-universal agreement among the panelists that colleges must do a better job of teaching their students to be good problem-solvers. The educators interviewed have made notable efforts to do this, but with only limited success. This study indicates that one reason for this may be that teaching problem-solving skills is more complex and more time-consuming than teaching technical content in a traditional

format. Students who are taught in a more traditional manner may find themselves ill-prepared to function in the modern workplace where problem-solving is expected from virtually all employees on a daily basis.

This study further indicates that some educators have demonstrated that problem-solving can be taught successfully to adults as part of a technical curriculum. They are doing this by teaching students how to use structured problem-solving methods and then providing well-designed activities that encourage students to use these methods to solve "real-world" problems. While the choice of a specific problem-solving method is not critical, this paper does recommend some important concepts that should be included when teaching problem-solving skills. In addition, instructors should incorporate into their existing technical courses more open-ended activities, which require the use of problem-solving skills.

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Carns, Tim, Ph.D.; Technology Development Director at Zilog (July 10, 2002).

Dunn, James; Electronics Technology Instructor at Boise State University (July 18, 2002).

Gardner, John, Ph.D.; Professor of Mechanical Engineering at Boise State University (July 22, 2002).

Hata, David; Instructor at Portland Community College (July 30, 2002).

Lonsdale, Edward; Manufacturing Systems Technology Program Head at Boise State University (July 23, 2002).

Moll, Amy, Ph.D.; Associate Professor in Mechanical Engineering at Boise State University (July 22, 2002).

Standen, Andy; Senior Engineer at Intel Corporation (July 30, 2002).

Willis, Mary Jane; Instructor at Albuquerque Technical Vocational Institute (July 31, 2002).

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